

DESIGN AND DEVELOPMENT OF LOW-COST VENTILATOR WITH ADJUSTABLE BREATHING RATE AND ASSISTED VENTILATION

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Smart ventilator, Arduino-based medical device, Adjustable breathing rate, Pandemic healthcare solutions, Rural healthcare innovation, Open-source medical hardware, Real-time patient monitoring, DIY ventilator design, Blood oxygen sensor integration.

Introduction:

The COVID-19 pandemic highlighted the critical need for accessible, cost-effective ventilators, especially in resource-limited settings where advanced medical equipment is scarce. Ventilators are essential for patients who experience severe respiratory distress and cannot maintain adequate oxygenation independently. However, commercial ventilators are often expensive and require specialized maintenance and operation, creating a barrier for many hospitals and clinics in low-income regions. The development of low-cost, easy-to-build ventilators can bridge this gap, providing essential respiratory support for patients during emergencies or in underserved areas.

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Our system makes use of blood oxygen sensor along with sensitive pressure sensor to monitor the necessary vitals of the patient and display on a mini screen. Also an emergency buzzer alert is fitted in the system to sound an alert as soon as any abnormalities is detected.

The entire system is driven by Arduino controller to achieve desired results and to assist patients in pandemic and other emergency situations.

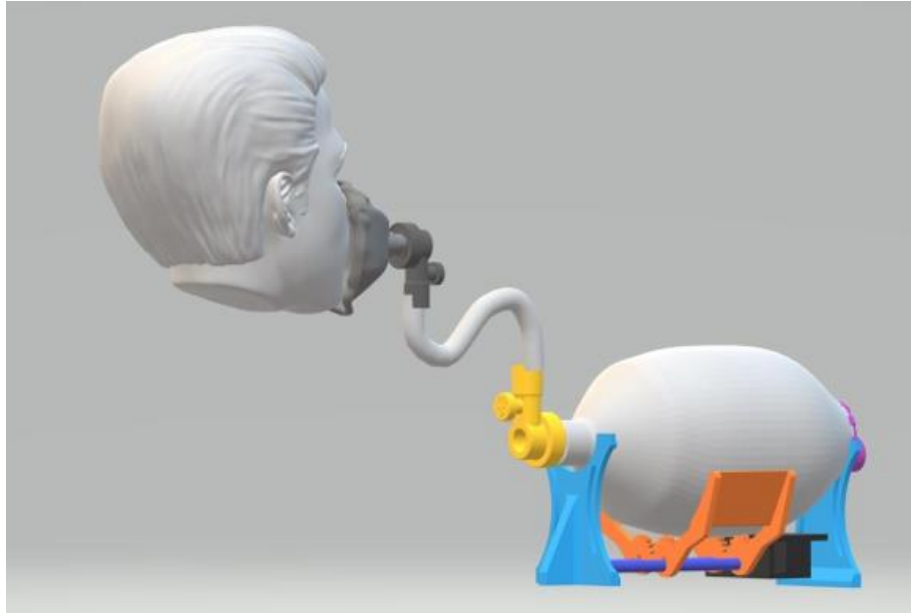


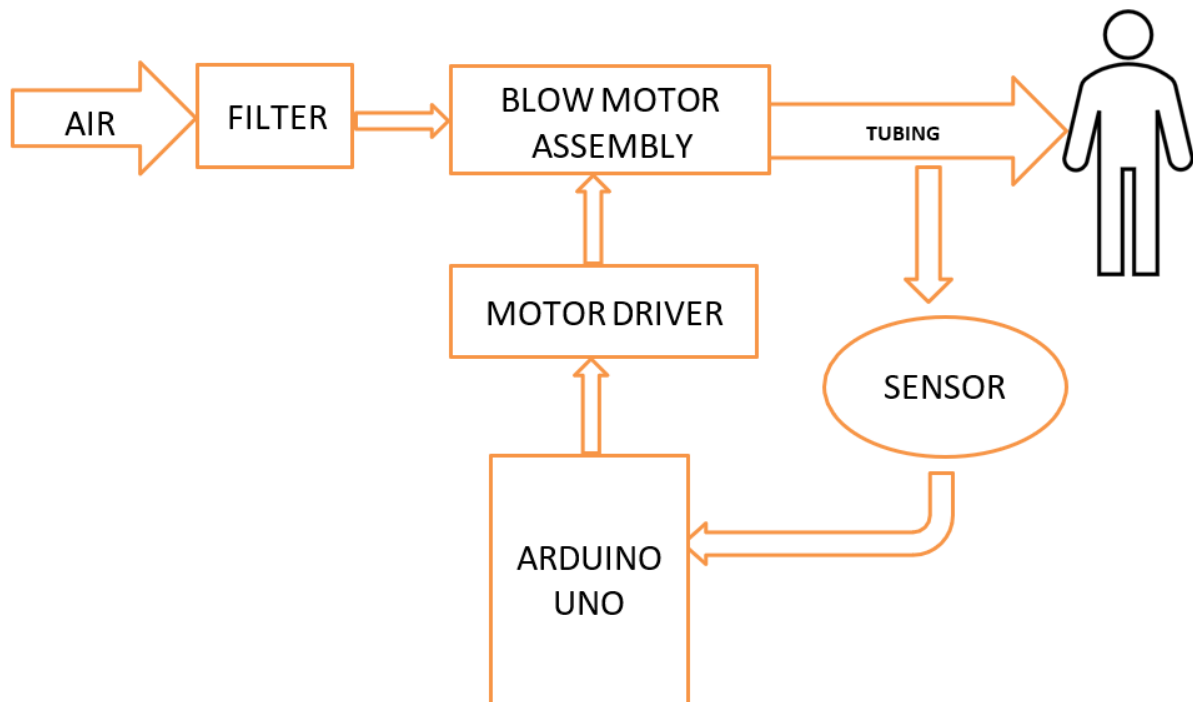
Figure 1: A view of Low-cost smart ventilation

Objectives:

- To deliver essential ventilatory support focusing on patient comfort and prioritizing patient safety.
- To ensure affordability and accessibility by incorporating latest technology with simplified operation.

Methodology:

The project involves the following methodology,



The block diagram illustrates the basic components and working of ventilator system:

- Air Source and Filter: Air enters the system through an inlet and passes through a filter to remove impurities, ensuring clean air is delivered to the patient.
- Blower Motor Assembly: This is the central component that generates airflow and controls the pressure needed to deliver air or a mixture of oxygen to the patient's lungs.
- Motor Driver: Controls the blower motor's speed and performance based on signals from the microprocessor, ensuring precise delivery of air.
- Microprocessor: Acts as the brain of the ventilator. It processes input signals from sensors and adjusts the blower and motor driver to meet the patient's breathing requirements. It ensures real-time control and operation.
- Sensor: Monitors parameters such as pressure, flow rate, or oxygen levels in the tubing to provide feedback to the microprocessor for system adjustments.
- Tubing and Patient Interface: Tubing delivers the air/oxygen mixture to the patient, maintaining a direct connection between the ventilator and the patient for respiratory support.

Result and Conclusion:

In conclusion, the proposed low-cost ventilator with assisted modes and variable BPM provides a viable and accessible solution for delivering respiratory support in resource-limited settings. By incorporating essential functionalities such as Assist-Control (AC) and adjustable BPM, and basic safety features like pressure monitoring and alarms, this ventilator addresses the fundamental needs of emergency ventilation at a fraction of the cost of conventional devices. Its modular, open-source design allows for local customization, easy assembly, and adaptability to different patient conditions and environmental factors, making it an ideal option for underserved areas.

While this system presents a promising alternative to high-cost ventilators, it is essential to conduct extensive testing, calibration, and ongoing refinement to ensure patient safety and reliability. With further validation and clinical trials, this device has the potential to be a scalable, life-saving technology, providing much-needed support in both routine care and emergency situations across low-resource healthcare environments. Ultimately, this system exemplifies the potential of low-cost, accessible innovation to address global health challenges and improve patient care where it is most needed.

Project Outcome & Industry Relevance:

- Personalized Respiratory Support: the system proposed here has the ability to adjust the breathing rate that allows the ventilator to be tailored to individual patient needs. This helps in managing patients with varying levels of respiratory distress based on faster or slower breathing rates.
- Enhanced Patient Comfort: the proposed system involves assisted operation features where the ventilator can work more in sync with the patient's natural breathing patterns, providing a more comfortable and less invasive experience
- Reduced Risk of Ventilator-Associated Complications: With the ability to fine-tune parameters such as breath rate, pressure, and volume, the ventilator can minimize risks like barotrauma (damage to the lungs caused by excessive pressure), polytrauma, or ventilator-associated pneumonia.
- Alignment with Government Health Initiatives: The project supports national goals of improving public healthcare access, especially in rural or underserved

areas, aligning with initiatives like 'Make in India' and 'Atmanirbhar Bharat' in the medical technology space.

- Support for Healthcare in Resource-Limited Areas: The project provides a cost-effective solution for delivering respiratory assistance in clinics or hospitals that lack advanced medical infrastructure. This is especially crucial during health emergencies such as pandemics.
- Relevant to the Biomedical Device Sector: By integrating sensors for vital monitoring and automated control mechanisms, the system reflects real-world trends in biomedical device development.

Working Model vs. Simulation/Study:

This project resulted in the development of a working physical prototype instead of being limited to simulations or theoretical modelling.

The system was constructed using real hardware components such as an Arduino Uno, blood oxygen and pressure sensors, a silicon ventilator bag, and a motor-driven mechanism.

Through physical testing, the team was able to evaluate performance in actual use scenarios, including variable breathing rates, patient-triggered assistance, and real-time alert systems. Unlike a simulation, the hands-on model provided valuable insight into sensor calibration, hardware synchronization, and user interaction under practical conditions.

This approach not only validated the design but also highlighted real-world challenges and refinements necessary for clinical deployment, making it a stronger foundation for further development and scaling.

Project Outcomes and Learnings:

- Successful Prototype Development: A functional, low-cost ventilator was built using Arduino, sensors, and basic components. It provides adjustable breathing rates and pressure support tailored to patient needs.
- Vital Monitoring Capabilities: The system accurately measures blood oxygen levels and exhaled pressure, helping prevent over-ventilation or under-ventilation.
- Emergency Readiness: The ventilator includes essential safety features like alarms, pressure monitoring, and battery backup, making it suitable for crisis

use in under-resourced areas.

- Understanding of Medical Device Functionality: Learned how ventilators operate, including pressure cycles, airflow regulation, and patient safety mechanisms.
- Awareness of Healthcare Challenges: Developed insight into the challenges of designing affordable medical equipment for areas with limited resources.

Future Scope:

The future scope of this project includes:

1. Integration with IoT for Remote Monitoring: Future versions can include Wi-Fi or Bluetooth modules to transmit patient data to doctors or monitoring stations, enabling remote supervision and telemedicine applications.
2. Advanced Ventilation Modes: Additional support for modes like SIMV (Synchronized Intermittent Mandatory Ventilation) or NAVA (Neurally Adjusted Ventilatory Assist) can be implemented to meet a wider range of patient needs.
3. Touchscreen Interface: Replacing traditional knobs and switches with a user-friendly touchscreen would improve usability and allow better control over ventilation settings.
4. Integration with Electronic Health Records (EHR): Patient data from the ventilator can be linked directly to hospital EHR systems for improved documentation and care continuity.
5. Miniaturization and Portability: By refining the design and using compact components, the device can be made more portable, making it ideal for ambulances or field use.
6. Regulatory Certification and Mass Production: With further testing and validation, the design can be optimized for certification by medical authorities (like CDSCO, FDA), allowing for large-scale manufacturing and deployment.